THE RELATION OF ECOLOGICAL FACTORS TO THE DISTRIBUTION AND CONTROL OF THE HORN FLY, *Haematobia irritans* (L.), UNDER RANGE CONDITIONS

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THE RELATION OF ECOLOGICAL FACTORS TO THE DISTRIBUTION AND CONTROL

OF THE HORN FLY, *Haematobia irritans* (L.),

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PREFACE

The author became aware of the need for further investigation to determine the ecological influences involved in controlling the horn fly, Haematobia irritans (L.), while working on the control of external parasites of livestock during the summer of 1962. After conferring with Dr. D.E. Howell, Professor and Head of the Department of Entomology, it was decided that a study of this nature would make an interesting and worthwhile thesis problem.

The author wishes to express appreciation to his major advisor and committee chairman, Dr. D.E. Howell, for thoughtful guidance and encouragement throughout the experimentation and in the construction of this manuscript. Sincere appreciation is expressed to Dr. J.V. Whiteman, Professor of Animal Science, for advice on statistical methods and for helpful suggestions in the preparation of this paper; to Dr. R.R. Walton, Professor of Entomology and Dr. E.D. Besch, Professor and Head of Veterinary Parasitology and Public Health, for their constructive criticism of the thesis manuscript.

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INTRODUCTION

Insects are today and probably through past ages have been one of the most adaptive of all animal life to changing foods and shifting climatic conditions.

One way to increase production of livestock economically is to control insects that plague animals and carry animal diseases. All of our domestic livestock are subject to attack by many kinds of insects. Constant irritation and blood loss reduce weight gains and milk production.

If we know the environmental requirements of an insect pest and the influence of changes on its population, it may be possible to predict the outbreak of the pest in advance or to develop methods which would keep the injurious species under control.

Successful control is based upon an understanding of the biology of the insect involved. Proper timing of insecticide application is possible only when the biology and seasonal population trends of an insect are known. The effects of climate or weather conditions upon the pest must be carefully studied, with the hope that the control will be based upon sound biological principles.

In the absence of successful biological control, the application of an effective insecticide is justified.

Small horn fly populations usually do not present an economic problem to the cattle industry in Oklahoma. Considerable annoyance occurs when infestations are in excess of 400 to 500 flies per head and control measures are advisable when the fly populations reach this number.

A large number of chemicals have been approved by the federal authorities for the control of horn flies on beef cattle, most of them have restrictions which limit the time of slaughter of the animals after application. Among those recommended for beef animals are Ciodrin, DDVP, ronnel, Ruelene, Co-ral, DDT, toxaphene, and methoxychlor.

Most systemic insecticides circulate in the blood vascular system for short periods of time following application. This results in insect control when the appropriate levels of the insecticide has been attained.

REVIEW OF THE LITERATURE

Ecological Factors

The abundance of parasites is frequently influenced by weather, but no definite general rules as to the relative effect upon the host and the parasites can be laid down. The test of abundance is abundance itself as shown by continuous, quantitative collections correlated with complete weather records.

Shelford (1926) stated that the number of individual parasites present after a period of hibernation, aestivation and cessation of activity is determined by or is markedly affected by weather and climate. The number of parasites surviving an adverse period is the basis upon which all increments must be built. The rate of development to maturity and the duration of reproductive life are influenced by weather.

The insects have adapted themselves to the climatic conditions in the regions where they naturally occur, and it is only when severe departures from these norms occur at a critical period in an insect's life that its numbers increase and decrease materially.

Hyslop (1941) and Glen (1954) pointed out that weather has long been known as a primary influence that holds in check many insect species with fantastically high reproductive potentials. A knowledge of the factors that underlie fluctuations in the populations such as temperature, moisture, and rate of evaporation is important in devising a method of control for a pest species.

Milne (1957) indicated that outbreaks of a species are simply due to the fact that conditions momentarily correspond or approximate to the ecological optimum. The complex of factors which actually affect control in the case of any species differs in composition from point to point and from year to year in the area of distribution.

Immature Stages. Horn fly oviposition takes place exclusively on fresh cattle droppings, and this is the only natural medium in which the larvae develop. The full-grown larvae pupate in the droppings or in the soil underneath. Therefore, anything that adversely effects the droppings would depress the potential population of horn flies.

Bruce (1964) showed that the third instar larvae are more resistant to low temperatures than those of the first and second instars. However, at a constant temperature of 19 C many mature third instar larvae survived less than a week and none survived for 30 days.

Mature horn fly larvae exhibit a definite sensitivity to moisture conditions when selecting a place to pupate. They may pupate in the dropping or as deep as 1.5 inches in the soil beneath the dropping. If the soil is excessively dry and growth rate rapid all pupae will be found in the moist part of the dropping, especially in close proximity to the lower surface. When the soil is moist and the dropping comparatively dry, most of the larvae move into the soil to pupate. Under some conditions (Bruce, 1964) the larvae pupate on the surface of the soil beneath the dropping.

The pupae are resistant to low temperatures and it is in this stage that the horn fly overwinters (Bruce, 1964). Exposure to a constant temperature of 19 C for 30 days had no apparent detrimental effect on pupae and a normal number of flies emerged.

Metabolism. Peairs (1914) stated that the rate of insect development is affected by temperature, and, other factors being constant, this rate increases in direct proportion to the increase in temperature, within the normal limits of development.

Uvarov (1931) found that it was imperative to compare the rates of gaseous exchange at different temperatures in the insects of exactly the same stage of development.

Wigglesworth (1939) pointed out that although insects are poikilothermic they are, to a great extent, orientated by temperature. Krogh (1941) showed that their rate of activity is directly related to rate of respiration.

Edwards (1946) working with Melanotus and Musca observed that their only adjustment to increased temperature was increased metabolism, and to decreasing temperatures is decreased metabolism, activity, and hibernation.

Wigglesworth (1939) found Haematobia larvae to have a preferred temperature range of 15 to 26 C, which accords closely with that of their normal breeding place.

Bruce (1964) observed the average time required for the development of horn fly larvae from hatching to pupation was 92.25 hours at a constant temperature of 31 C. In the field, during the summer, the larval period was approximately four days.

Overwintering. The approach of winter affects practically all insects, whether they hibernate in the state of diapause, or are simply brought into a quiescent state by low temperature. During the summer, food and breeding are the most important factors in the activities of insects, but with the approach of cold weather most insects must adjust to their changing habitats in order to survive.

Winter mortality is probably the main factor controlling the abundance of most insects in temperate latitudes. Hibernating insects are, generally speaking, less susceptible to the winter cold. The resistance of an individual insect to cold may be greatly increased by a "hardening", which is accomplished either by the gradual lowering of environmental temperature, and by the reduction of the free water in the organism (Uvarov, 1931).

The kind of shelter under which an insect hibernates as well as the parts played by heredity in these phenomena are very important for a high percentage of survival (Bodine, 1932).

The first references to an arrest of development in the life cycle of the horn fly were made by Smith (1889) and Marlatt (1910), in the vicinity of Washington D.C. and New Jersey. They indicated that the horn fly overwinters either in the adult or in the pupal stage. Fletcher (1892) and Winn (1893) showed evidence that the fly overwintered in the pupal stage in the colder regions.

Larsen and Thomsen (1941) and Hammer (1942) found that some pupae in their cultures stopped development. Observations in southern Alberta by McLintock and Depner (1954) indicated that a period of arrested development or diapause occurred in some late season puparia. The effect of photoperiod acting on the adult of the previous generation or on the developing unlaid egg is responsible for the predisposition to enter diapause. This predisposition becomes more intense as the season progresses, and tends to overcome the diapause-inhibiting effects of higher rearing temperatures.

Depner (1961) reported average time to first puparium formation was 105 days at 19 C, 5.6 days at 24 C, and 3.7 days at 30 C under laboratory conditions at constant temperatures. Under laboratory conditions all feeding horn fly larvae were killed by temperatures below 0 C but mature larvae were able to survive the winter temperatures in parts of Canada. The larvae overwinter only when environmental temperatures are not favorable for puparium formation. Cattle droppings from late summer have been found to contain living mature larvae in winter.

Diapause appeared at 19 C in puparia reared from eggs laid in the fourth week of July and thereafter. Diapause did not occur at 24 C and 30 C in pupae from eggs laid before the first and third weeks of September. Depner (1962) found that under natural conditions, diapause was very rarely found in pupae developing from eggs laid in spring or early summer but became more common as the season advanced. He observed that the shorter the photoperiod, the greater the percentage of pupae that go into diapause. By increasing the photoperiod there was a corresponding decrease in the percent of pupae going into diapause. The increase in wavelengths of light at given photoperiods effected the percent of pupae going into diapause. Increased fluorescent and ultraviolet light decreased the percentage of diapause at given photoperiods.

Horsfall (1962) indicated that the larval threshold for development was about 13 C and the optimum was 32.3 C. The larvae in preparation for overwintering either transform into pupae at the base of the dung on the ground surface or burrow about one-half inch into the soil.

In a three year study (Bruce, 1964) cattle droppings were infested with 200 to 300 eggs or newly hatched larvae, and placed in a pasture under individual screen cages. This was repeated each week from late September until the end of the horn fly season or about November 1. Flies emerged during the fall from the earlier tests, while the immature larvae of the later tests were killed by the low temperatures. Those insects that reached the pupal stage survived and flies emerged the following spring.

Emergence. During the summer approximately 99 % of the flies emerge in the afternoon, mostly between 3:00 and 6:00 pm. In the spring and fall adult emergence has been observed at all times of the day and often at night (Bruce, 1964).

Population Numbers. Insects of dry countries are much more abundant and active in spring and autumn, while at the height of summer many of them are known to undergo a period of low population numbers (Uvarov, 1931).

Bruce (1940, 1942) found that in the southwestern United States the horn flies usually appear in March and build up a large population during April and May. The most favorable climatic conditions, warm, damp, cloudy weather, occuring during this period are ideal for horn fly development. Then, owing to hot, dry weather, they decrease in numbers until late August, when late summer rains are conducive to a rapid multiplication. From early in October to November the activity of horn flies is gradually diminished by cool weather. In summarizing these effects, Bruce states, " In general it may be stated that temperature determines the presence of horn flies and moisture conditions determine the abundance".

Flight. The dependence of flight (Uvarov, 1931) on temperature conditions is exhibited by many insects. In blood-sucking insects feeding is dependent, like all other activities, on the air temperature and is determined by the temperature of the host as well. While temperature conditions are important it is natural to suggest that the most important factor in passive dispersal of insects is wind, especially that of high velocity. However, Bruce (1938, 1964) and Hammer (1942) concluded from observations that the horn fly does not travel any considerable distance under range conditions. The flies are quite active, often making short rapid flights from one part of the animal to another, darting to the ground and back to the host, and occasionally from one animal to another, but they are not strong fliers and it is doubtful if they are capable of a long substained flight.

Host Relationship. Hammer (1942) gave evidence that horn flies are extremely sensitive to temperature changes. He reports that when the weather is cloudy or cool and there is no rainfall the flies rest on the backs of the cattle, but when the weather is bright and sunny, their resting place seems to depend on the air temperature. At air temperatures of 19 C flies were found resting on the backs of the cattle, but when the weather is bright and sunny, their resting place seems to depend on the air temperature. At air temperatures of 26 to 29 C, the flies were always underneath on the belly, on the lower parts of the hind legs, and on the scrotum or the udder. On cool nights the flies gather in the angles of the udder and at the elbow and at the base of the horns. Evidence was given that the flies prefer a temperature of about 37 C and he suggested that the moisture requirements are very high at such a temperature.

Bruce (1964) observed the horn fly to seek that portion of the animal most suitable to its welfare. On cool, sunny days the flies congregated on the side of the animal exposed to the sun, while on hot, sunny days they preferred the opposite side, or more especially along the median line of the belly. Bruce (1964) in disagreement with Hammer (1942), stated that " the flies cluster around the base of the horns and between the hind legs, where they gain the proximity to the body heat of the animal during cool, cloudy weather with temperatures below 20 C".

Bruce (1964) found only a small percentage of the flies to rest on the horns during warm weather, their most common habitat being near the ends of the hairs. As the temperature becomes cooler, the flies were observed to move closer to the skin of the animal.

On one occasion during a rain storm when the air temperature was 9 C, the flies were observed half-buried among the long hairs on the back, sides, neck, and in the grooves at the sides of the base of the tail (Hammer, 1942).

Control

Early Methods of Control. Smith (1889) recommended the scattering of cattle droppings by dragging brush or a spike-toothed harrow over the pasture or by the use of a manure fork or shovel, and the use of lime to destroy the horn fly larvae.

Repellents. Most of the early research on horn fly control was directed toward the use of repellents. The materials used varied from train oil, train oil and carbolic acid or sulfur, pine tar, tallow and carbolic acid, and axle grease. Modern repellents such as Crag Fly Repellent, Tabatrex, MGK 11, MGK 326, and many others have been used for protecting cattle from the horn fly. Bruce (1964) indicated that repellents have not been effective in the past and that this method of control has not met with popular usage.

Sprays. Smith (1889) reported that the first successful killing agents used against the horn fly were pyrethrins and tobacco powders applied as sprays. Pyrethrum sprays continued to be the most satisfactory treatment for the control of horn flies until the advent of DDT. Bruce and Blakeslee (1946) conducted the first field test to determine the efficiency of DDT in the control of horn flies in Florida in 1943 to 1945. The effectiveness of this chlorinated hydrocarbon insecticide against the horn fly, and other insect pests, stimulated research in the development of other chlorinated insecticides and the newer organophosphates (Bruce, 1964).

Cutkomp and Harvey (1958) reported that significant weight gains were realized on cattle which had been treated with sprays to reduce the number of biting flies. They indicated that on the basis of these results, and a study of the weather records, a profitable return from biting fly control might be expected in most years.

Internal Medication. Gallagher (1928) first attempted the internal medication of cattle for the purpose of rendering their droppings unsuitable for the development of horn fly larvae, by placing various substances in the drinking water.

Trials conducted by Knipling (1938) indicated that horn fly larvae could not develop in the droppings of cattle that had been given orally 0.1 g of phenothiazine per kg body weight. Phenothiazine mixed with fresh cow manure in concentrations as low as 0.0025% was found to give 100% control of horn fly larvae.

Bruce (1940) administered several materials to cattle mixing them with bran, water, or if they were distasteful to the animal, they were placed in a capsule and given with a balling gun. A 500 g sample of the droppings were infested with 50 to 100 horn fly eggs and placed on 800 g of moist sand in a pan for observation. Rotenone was the most effective chemical tested with doses as low as 0.1 g/cwt giving remarkedly high kills of the larvae. A dose of 0.4 g/cwt was found to kill all horn fly larvae.

Eddy et al. (1954) in tests at Kerrville, Texas, found lindane at 100 ppm to be particularly effective against horn flies. The treatment proved lethal to flies feeding on the animal as well as the manure for at least 21 days after treatment. Dieldren and aldrin proved also to be toxic, while an animal fed chlordane showed no apparent toxicity to horn fly larvae.

Eddy and Roth (1961) evaluated ronnel in experiments whereby it was mechanically added to fresh cattle feces to which was added horn fly larvae. The minimum lethal dosage to 50 horn fly larvae was found to be 0.5 to 1.0 ppm.

In feeding tests extending 91 days, Drummond (1963) found 0.5 and 1 mg/kg/day of Co-Ral and 1 mg/kg/day of Bayer 22408 to be essentially 100% effective in preventing the development of horn fly larvae.

Medley et al. (1963) in field tests with low-level feeding of ronnel found that some apparent control was obtained with levels as low as 4 mg/kg/day when maintained for periods longer than one week. Consumption of ronnel in the mineral-block form varied considerably from group to group and from week to week within a group. A level of 3.5 mg/kg/day of ronnel was inadequate to prevent a buildup in the number of horn flies. Wallace and Turner (1964) evaluated the effectiveness of ronnel in a mineral mixture utilizing Berlese funnels and small core samples from fecal droppings. Twenty-five random cores 5 inches in diameter were placed in Berlese funnels for 4 to 5 days and the number of larvae were removed and counted.

Simco and Lancaster (1964) reported that feeding cattle a commercially formulated granular mineral mixture containing 5.5% ronnel gave excellent control of horn flies. Each animal on the test consumed approximately two pounds of medicated mineral per month. Pre-treatment horn fly counts averaged 450 per head and after the initial knockdown approximately 11 horn flies per animal were observed during the remainder of the test.

Tests conducted in Georgia by Baird (1964) showed that phenothiazine gave no significant reduction in horn fly numbers while ronnel at low-level consumption gave 89 and 96% control.

Tests conducted in Kentucky (Knapp, 1965) indicated that free choice mineral blocks and granules containing 5.5% ronnel gave horn fly control of 96% on cows to 100% on calves. The consumption of ronnel granules averaged 4.6 mg/kg/day. In two experiments with mineral blocks consumption averaged 6.0 mg/kg/day and 9.3 mg/kg/day.

MATERIALS AND METHODS

Test Insects. Natural populations of horn flies *Haematobia irritans* (L.) were used in the field tests which were conducted at Lake Carl Blackwell, Stillwater, Oklahoma and the Southern Great Plains Field Stations at Woodward and Supply, Oklahoma.

The larval horn flies used in the laboratory were received from Kerrville, Texas, USDA Laboratories via surface mail. Horn fly eggs were mailed from Kerrville on Friday and first instar larvae were received in Stillwater the following Monday afternoon during the five week laboratory testing period.

Test Locations. Field experiments were conducted at the Oklahoma State University Animal Science Experimental Range located on the north side of Lake Carl Blackwell and at the Southern Great Plains Field Station at Woodward and Supply, Oklahoma.

The experimental range at Woodward and Supply, Oklahoma consisted of sand-sage grassland type pastures. The pastures varied in size from 10 acres to 213 acres. The horn fly control treatments were superimposed on groups of steers on grassland utilization studies being conducted by the USDA. The steers were from the same herd of commercial cattle and were uniform in age. The experimental groups varied from 2 to 16 head of Hereford steers per pasture. These animals obtained their water from water tanks supplied from windmills with each pasture having only one water source.

The experimental range at Stillwater, Oklahoma was of the tall-grass prairie type. The cattle groups consisted of eight groups of 29 to 33 Angus cows each of which was randomly allotted to breeding groups by the Animal Science Department at Oklahoma State University. The water source was obtained from Lake Carl Blackwell which offered extensive lake frontage to each test group.

Ecological Factors

Winter Survival. Tests were conducted during the fall and winter of 1963 to determine the stage of overwintering, the fecal deposit-overwintering stage association, and the pasture type-overwintering stage relationship of the horn fly in Oklahoma.

Two pasture types were compared in this study. One type consisted of open grassland pastures which were in excellent grazing condition. The second pasture type was a heavily timbered pasture with limited grass coverage.

Twenty-five fecal deposits were thoroughly examined each month from September until January. The diameter and center thickness of each fecal deposit were measured and recorded. The deposit was then carefully removed and examined for the overwintering stage. The ground area underneath the deposit was also examined for immature horn flies to a depth of 1.5 inches.

The fecal deposit was divided into two areas for determining the overwintering stage-fecal deposit relationship. The outer 2 inches were designated as the outer area and the remaining part the center area. The ground surface directly beneath the deposit was similarly divided and the number of overwintering horn flies found in these areas was recorded. Table 1.

Table 1.--Data record sheet for recording the overwintering location of horn flies under fecal deposits in Oklahoma.

Fecal Deposit			Soil Surface		Beneath Soil Surface	
Number	Diameter	Thickness	Edge	Center	Edge	Center
1						
.						
.						
.						
25						

Weather Influences. The effects of weather on adult horn fly populations were determined by comparing the adult fly counts on untreated herds of cattle with the daily weather data published monthly by the United States Department of Commerce Weather Bureau. The effects of temperature, wind, and precipitation were studied with data collected at Lake Carl Blackwell and Fort Supply, Oklahoma in 1964. The groups of cattle receiving no horn fly control treatments were used in these studies.

In August of 1964 a study was conducted to determine the time of day the adult horn flies emerged and sought a host. A mature Angus bull was utilized for this study. The animal was led through a large open pasture and stopped every 25 yards to determine the number of horn flies present. Prior to testing, the bull was treated with a mild acetone spray to remove the horn fly population present and allowed to stand in the shade for one hour.

The first test was conducted from 9:00 until 11:00 am and the second test was conducted from 3:00 until 5:00 pm. The bull was stopped and the number of horn flies evaluated 50 times during each of the two tests. The number of horn flies present on the sides and top line of the animal at each stop were counted and the previous count subtracted from this number to indicate the number of newly arrived horn flies.

Larval Metabolism Studies

A 4 X 3 factorial design was utilized in these studies to determine the effects of constant temperatures on the metabolism of horn fly larvae. The effects of constant temperatures of 4.5, 10, 16, and 21 C at 24, 72, and 120 hours were determined in these tests.

Temperature Control. The larval horn flies utilized in these tests were received from Kerrville, Texas in 4 inch square plastic Petrie dishes containing approximately 500 horn fly larvae each.

Seventy first instar horn fly larvae were selected at random and were placed on a 100 g sample of fresh cow manure and each test group was stored in a half pint ice cream carton. Each carton of horn fly larvae was randomly assigned to a constant temperature for the duration of the testing period. The cartons were held in temperature control cabinets which were accurate to $\pm$ 2 C in the laboratory.

Metabolism Measurements. Thirty munutes prior to testing, 15 horn fly larvae were randomly removed from each of their holding cartons and a wet weight measurement was taken and recorded. The larvae were then transferred to Warburg flasks containing 0.5 ml Ringer's solution in the cup and 0.1 ml KOH in the 2 inch well. The flasks were then attached to the manometers of the Warburg apparatus and the metabolism evaluation initiated. The flasks and their corresponding manometers were picked at random so that no temperature treatment would consistently be measured in the same testing device. The Warburg apparatus was set at a constant temperature of 25 C for each of the tests. The tests were conducted for 90 munutes with metabolism measurements recorded every 15 minutes.

At the conclusion of each test the larvae were removed from the flasks and placed in 2 inch diameter aluminum drying pans and oven dried for 24 hours. At the end of the 24 hour period the dry weight of the larvae was determined in milligrams.

The metabolism measurements were recorded in μl O_2 /mg dry wt/hour. The following calculations were utilized to determine these measurements:

1. The test manometer readings were corrected by reference to the control manometer to eliminate the atmospheric changes occuring prior to each reading.

2. The corrected 90 minute readings were divided by the μl O_2/mg dry weight/90 minutes.

3. The μl O_2/mg dry weight/90 minutes was then divided by 1.5 to obtain the μl O_2/mg dry weight/hour.

Control

The Lake Carl Blackwell 1963 and 1964 control studies were designed to show the effects of medicated mineral mixtures for controlling horn flies under range conditions. These tests were made to determine the treatment which showed the highest consumption of the active chemical, ronnel in mg/kg/day, as well as the extent of horn fly control.

<u>Lake Carl Blackwell 1963</u>. Tests were conducted at Lake Carl Blackwell in 1963 to determine relative consumption rates of granular and block formulations of medicated mineral supplements and the fly control obtained under rangeland conditions. Both forms of the mineral contained 5.5% ronnel in a complete mineral mixture.

Five groups of mature cows weighing approximately 900 pounds each were used as test animals, two groups receiving the block form, two groups receiving the granular form, and one group receiving a granular form which was non-medicated. Table 2 shows the treatments, the number of test animals per pasture, and the approximate number of acres in each pasture.

Table 2.--The 1963 test design at Lake Carl Blackwell, Payne County, Oklahoma.

Cow Group - Treatment	Acres per Pasture	Cows per Pasture	Formulation
1	250	30	5.5% ronnel-granular
2	250	35	5.5% ronnel-block
3	250	35	5.5% ronnel-granular
4	250	34	5.5% ronnel-block
5	250	34	non-medicated-granular

The trial was conducted for a period of 97 days beginning July 5 and ending October 10, 1963 within which consumption measurements were taken seven times during the treatment period.

The minerals were contained in wooden mineral boxes which measured 2 feet in length by 1 foot in width by 6 inches in depth. Fifty pounds of mineral supplement were placed in the mineral boxes at the beginning of the test and the amount consumed was replaced at regular intervals. Two mineral boxes for every 30 head of cattle were placed in each pasture. One box was located near the cattle's loafing area and the second box was placed in a position between the loafing area and the water source. These boxes were shifted as required by the movements and habits of the cattle.

The consumption was determined by weighing the portion remaining in the boxes.

Horn fly counts were made on 10 different occasions during the trial. The number of horn flies were counted on 10 head of cows at random from each group and the average number of horn flies for each group was calculated and recorded.

The cattle in these test groups were rotated two times during the trial. The mineral boxes for these groups were carried with the cattle to the next pasture location. After rotation the habits of the cattle in their new environment were closely observed in order to place the mineral boxes in the most accessible positions.

Lake Carl Blackwell 1964. The 1964 trial was conducted to determine if the rate of consumption of a mineral mixture could be controlled by the addition of dicalcium phosphate or steamed bone meal and still provide effective horn fly control.

Eight groups of mature Angus cows were used as test animals. Four groups were located at one central corral and separated from the other four groups by approximately one mile. These animals weighed approximately 900 pounds and were seven and eight years old. The four treatments were randomly assigned to the cow groups. Table 3 shows the treatments, number of animals per group, and the approximate number of acres per pasture.

Table 3.--The design of the 1964 horn fly control trials at Lake Carl Blackwell, Payne County, Oklahoma.

Cow Group - Treatment	Acres per Pasture	Cows per Group	Formulation
1	250	29	6.0% ronnel-base mineral
2	250	29	4.0% ronnel-2 parts base + 1 part bone meal
3	250	29	4.0% ronnel-2 parts base + 1 part dicalcium phosphate
4	250	33	non-medicated base material
5	250	29	6.0% ronnel- base material
6	250	29	4.0% ronnel-2 parts base + 1 part bone meal
7	250	29	4.0% ronnel-2 parts base + 1 part dicalcium phosphate
8	250	29	non-medicated base material

The dicalcium phosphate or steamed bone meal formulations were added to the base formulation containing 6% ronnel by placing the two ingredients into a hand-operated seed treating drum and rotating vigorously until the minerals were thoroughly mixed.

The trial was conducted for a period of 74 days beginning June 22 and ending September 3, 1964, during which dates consumption measurements were taken seven times. The minerals were contained in wooden mineral boxes described in the preceding section except that only 25 pounds of mineral were placed in the boxes at one time. Two mineral boxes were placed in each pasture. The boxes were located as described in the previous section.

The consumption data were determined volumetrically by the use of a board exactly fitting the width and depth of the mineral box and forcing the mineral to one end of the box to a uniform depth. When measurements were taken in the field the mineral remaining in the box was measured and compared with previously determined volumes.

Measurements were estimated to the nearest pound.

A box, inaccessible to the animals containing the mineral, was utilized to determine the loss due to wind and rainfall. At the end of the trial the consumption data were corrected by these values to the nearest pound. Adult and larval horn fly counts and consumption data were obtained on the same dates. The adult counts were made as described in the 1963 Lake Carl Blackwell trial. The larval counts were obtained by randomly collecting one-half of each of 10 fecal droppings from each pasture. These samples were approximately 5 days old when collected. The fecal samples were carried to the laboratory in wooden trays and placed in Berlese funnels 11 inches in diameter and containing a 200 watt bulb approximately 3 inches above the samples at the nearest point. The samples were supported on $\frac{1}{2}$ inch mesh hardware cloth.

Two samples from the same treatment were placed in each Berlese funnel and empty one-half pint fruit jars were attached to the bottom of the funnels for collecting the larvae. After the funnels were prepared the light bulbs were turned on simultaneously. The fecal samples were left in the funnels for a period of one hour. At the end of the time period the jars were then removed from the funnels and the contents of each emptied into a glass petrie dish. The number of larval horn flies, blow flies, and adult beetles was counted and recorded.

The cattle in these test groups were rotated three times during the trial. The mineral boxes were moved with each group as it was rotated and the habits of the cattle were carefully observed during the time they were adjusting to their new environment in order to place the mineral boxes where they would be used most.

Fort Supply 1964. Tests were conducted to determine the effectiveness of consumption and horn fly control of five mineral mixtures fed free-choice, under a variety of pasture management conditions, on native range. The treatments utilized in this trial are shown in Table 4.

Table 4.--Mineral formulations utilized in the 1964 trial at Fort Supply, Oklahoma.

Treatment	Percent ronnel	Formulation
1	0.0	Non-medicated mineral mixture
2	5.5	Non-trace mineralized mixture
3	6.0	Base mineral + 2:1 Ca to P
4	6.0	Base mineral + 3:1 Ca to P
5	6.0	Complete trace mineralized mixture

The treatments were assigned to steer groups which were being utilized for range management studies (Table 5). The treatments were assigned in blocks to cause isolation of the control treatment and to minimize complications with the existing range experiments. The comparisons used to show the effects of range management on consumption and horn fly control are shown in Table 6.

The trials were conducted for a period of 80 days beginning July 14 and ending October 1, 1964. Consumption measurements were taken five times during the trial at about 15 day intervals.

The minerals were contained in two plastic dishpans 12 inches square and 6 inches deep. These containers were then placed in whirlwind mineral feeders to protect the mineral materials from the weather elements. Two pounds of mineral per head of steers were placed in the feeders at the beginning of the trial. The feeders

Table 5.--The test design of the 1964 trial at Fort Supply, Oklahoma.

Pasture Numbers	Range Management Practice [a]	Number of Acres	Number of Steers	Treatment Number	Number of Samples [b]
17	Summer grazed steers wintered on weeping lovegrass	160	12	1	4
18	Continuous yearlong grazing	213	16	3	3
19	Summer grazed steers wintered on weeping lovegrass	160	12	2	2
21	Continuous yearlong grazing	107	8	3	3
23c	Yearlong grazing of sagebrush pastures	25	3	2	2
24	Continuous yearlong grazing	107	8	4	3
26b	Yearlong grazing of sagebrush pastures	25	3	3	2
27ab	Continuous yearlong grazing	50	7	2	2
27cd	Continuous yearlong grazing	50	7	1	4
32a	Yearlong grazing of sagebrush pastures	25	3	2	2
32c	Yearlong grazing of sagebrush pastures	25	3	2	2
33ab	Moderate stocking rate. No stilbestrol implants	50	6	5	2
37ab	Continuous yearlong grazing	107	8	4	3
38a	Heavy stocking rate. No stilbestrol implants	50	9	4	2
38c	Moderate stocking rate [c]	50	6	4	2
39e	Heavy stocking rate [c]	50	9	4	3
39w	Moderate stocking rate. No stilbestrol implants	50	6	4	2
40e	Heavy stocking rate. No stilbestrol implants	50	9	5	3
41s	Heavy stocking rate [c]	50	9	5	3
42n	Moderate stocking rate [c]	50	6	5	2

[a] All steers fed 1.5 pounds of "cake" (41% protein cottonseed crumbles) during the winter, implanted with 12 mg of stilbestrol on November 1 and May 1 and stocked at a moderate grazing rate, unless otherwise noted.

[b] The number of one-half fecal samples taken from each pasture.

[c] Also received 3 pounds of "cake" in winter, and 1 pound of cottonseed crumbles July 29 to September 29.

were checked periodically between scheduled weighings and additional material was added if necessary.

Table 6.--The treatment comparisons made at Fort Supply, Oklahoma in 1964.

Treatment Numbers	Pasture Numbers
1 vs 2	17 & 19
2 vs 3	19 & 18
3 vs 4	18 & 37ab
4	37ab vs 38a
4 vs 5	38a & 40e
1 vs 2	27ab & 27cd
2	27ab vs 32a
2 vs 3	32a & 32c
3	32c vs 21
3 vs 4	21 & 24
4	24 vs 39e
4 vs 5	39e & 41s
2 vs 3	23c & 26b
4 vs 5	38c & 42n
4 vs 5	39w & 33ab

The amount of mineral consumed was measured by weighing the material left in the feeder and subtracting this amount from the number of pounds remaining in the feeder on the last weighing plus any added during the period. One whirlwind feeder was placed in each pasture as near as possible to the water source.

Adult and larval horn fly counts were made on Monday of each week during this trial. The adult counts were made in the same manner as described for the 1963 Lake Carl Blackwell tests. The larval horn fly counts were made by collecting one-half fecal deposit samples from each of the treatment pastures, approximating as closely as possible one sample for every three head of steers on the treatment. The number of samples examined from each pasture are shown in Table 5.

After collection, the fecal samples were transported to the laboratory at Oklahoma State University and evaluated by the method described for the 1964 Lake Carl Blackwell tests.

The cattle in some of the treatment groups were rotated periodically and at each rotation their mineral mixtures were moved accordingly.

RESULTS AND DISCUSSION

Ecological Factors

Winter Survival. The pupal stage of the horn fly survives the winter in Oklahoma. The author observed only the pupal stage during the entire overwintering study.

The total number of pupae found overwintering in open and heavily timbered pastures was 125 and 49, respectively. There were no overwintering horn fly pupae found in the heavily timbered pasture during the months of October, November, and December, although pupae were continuously found during these months in the open grassland pasture. However, pupae were obtained from the heavily timbered area until the end of September.

The open pasture was observed to provide more protection against the changing climatic conditions due to the vegetation below and surrounding the fecal deposit. The soil in the heavily timbered pasture was almost void of any vegetation thereby offering little if any protection to the overwintering horn fly pupae from erosion by rain and wind, and from sudden temperature changes.

The results of the overwintering stage-fecal deposit relationship study are shown in Tables 7 to 10. Tables 7 and 8 compare the relationship in the open and heavily timbered pastures as to whether the pupae were found on the surface or beneath the surface of the soil as well as the edge or center preference.

Table 7.--Frequency of finding horn fly pupae on and beneath the surface of the soil under fecal deposits in open pastures.

Number of Pupae Edge of Deposit	Number of Pupae Center of Deposit						
	0	1	2	3	4	5	6
SURFACE							
0	49	24	10	5	1	2	0
1	4	0	1	1	0	0	1
2	1	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	1	0	0	0	0	0
BENEATH SURFACE							
0	87	4	2	0	1	0	0
1	3	0	1	1	0	0	0
2	0	0	0	1	0	0	0

Table 8.--Frequency of finding horn fly pupae on and beneath the surface of the soil under fecal deposits in heavily timbered pastures.

Number of Pupae Edge of Deposit	Number of Pupae Center of Deposit									
	0	1	2	3	4	5	6	7	8	9
SURFACE										
0	94	4	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	2	0	0	0	0	0	0
BENEATH SURFACE										
0	93	1	1	0	1	0	0	0	0	0
1	0	1	0	0	0	0	0	0	0	0
2	1	1	1	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	1

The data from this study show that in the open grassland pasture more pupae were found on the surface of the soil beneath the fecal deposit than beneath the surface to a depth of $1\frac{1}{2}$ inches, while the data from the heavily timbered pasture shows that more pupae were found beneath the surface of the soil. These data also show that more pupae were found in the center than the edge of the fecal deposit area regardless of whether they were on or beneath the surface of the soil.

In the open grassland pastures only 49 out of the 100 fecal samples observed did not contain at least one pupae on the surface of the soil, while 87 deposits were found that did not have pupae beneath the surface of the soil. The data from the heavily timbered pasture shows that seven fecal deposits were observed to contain a total of 35 pupae beneath the surface of the soil to a depth of $1\frac{1}{2}$ inches. Six fecal samples were observed to contain a total of 14 pupae on the surface of the soil.

The results of this entire study were combined to show the effects of diameter and thickness of the fecal deposit on the overwintering of the horn fly. The diameter of the fecal deposit has a direct relationship to the ability of the horn fly to survive the winter.

Tables 9 and 10 show the effects of fecal deposit diameter and thickness on the overwintering of the horn fly. The largest number of pupae were found associated with fecal deposits having a diameter of 8 to 16 inches. These larger deposits were observed to offer the greatest amount of protection from the environmental factors. It is also evident that it is within this range of diameters that the largest number of fecal deposits are encountered.

Table 9.--Frequency of finding horn fly pupae under fecal deposits of variable diameters.

Diameter in Inches	Number of Pupae													
	0	1	2	3	4	5	6	7	8	9	10	11	12	18
3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	3	0	1	0	0	0	0	0	0	0	0	0	0	0
6	4	4	0	0	1	0	0	0	0	0	0	0	0	0
7	2	0	0	0	0	0	0	0	0	0	0	0	0	0
8	11	2	3	1	0	1	0	0	0	0	0	0	0	0
9	0	0	1	0	0	0	0	0	0	0	0	0	0	0
10	20	8	4	1	2	1	0	0	0	0	0	0	1	0
11	0	1	0	0	0	0	0	0	0	0	0	0	0	0
12	7	5	2	3	1	3	0	0	0	0	0	0	1	1
13	3	1	2	0	0	0	0	0	0	0	0	0	0	0
14	10	3	1	0	1	0	2	0	0	0	0	0	0	0
15	1	0	0	0	1	0	0	0	0	0	0	0	0	0
16	2	3	0	1	0	0	0	0	0	0	0	0	0	0

A range of 3 to 6 inches in thickness was observed to offer the most suitable protection for the overwintering pupae. The fecal deposits having a center thickness of less than 3 inches were not observed to provide adequate protection from the weather elements because they tended to dry out and many lost their cohesiveness. Those deposits having a thickness of more than 6 inches were also observed to provide very little protection from the changing climatic conditions. The fecal deposits having small diameters were easily overturned which exposed the microclimate underneath, however, only the deposits remaining upright were used for this study.

Table 10.--Frequency of finding horn fly pupae under fecal deposits of variable thickness.

Thickness in	Number of Pupae													
Inches	0	1	2	3	4	5	6	7	8	9	10	11	12	18
2.0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	1	1	0	0	0	0	0	0	0	0	0	0	0	0
3.0	13	3	4	2	2	0	0	0	0	0	0	0	0	0
3.5	0	1	0	1	0	0	0	0	0	0	0	0	0	0
4.0	9	4	6	2	3	1	0	0	0	0	0	0	0	1
4.5	0	1	0	0	0	0	0	0	0	0	0	0	0	0
5.0	12	6	2	3	1	1	0	0	0	0	0	0	2	0
6.0	8	6	1	1	1	0	0	0	0	0	0	0	0	0
7.0	3	0	1	0	0	0	0	0	0	0	0	0	0	0
8.0	6	0	0	0	0	0	0	0	0	0	0	0	0	0

Weather Influences. The results of the study conducted to determine the effects of weather on adult horn fly populations at Lake Carl Blackwell, Payne County, Oklahoma in 1963 and 1964 and Fort Supply, Oklahoma in 1964 are shown in Tables 11, 12, and 13 respectively.

The results of this study indicate that the most important weather influences on horn fly numbers are temperature and precipitation. It seems doubtful that wind and evaporation have any influence on horn fly populations.

Table 11.--The effects of weather on horn fly populations at Lake Carl Blackwell 1963 for the months of July, August, September, and October.

	T[a]	T	T	T	W	W	W	W	E	E	E	E	P	P	P	P	HFC	HFC	HFC	HFC
Date	Jul	Aug	Sep	Oct	Jul	Aug	Sep	Oct	Jul	Aug	Sep	Oct	Jul	Aug	Sep	Oct	Jul	Aug	Sep	Oct
1	96	97	88	79	2.3	1.6	1.6	2.3	.48	.28	.07	.58			.3					
2	97	97	96	92	1.7	2.7	3.4	2.3	.38	.52	.27	.58						200		
3	97	96	93	95	1.8	1.5	1.9	.6	-	.20	.03	.09								
4	98	95	85	96	2.7	2.5	.6	.4	.49	.39	.73	.27			.8				400	
5	99	97	91	94	3.8	1.1	1.5	.7	.51	.39	.01	.22					300			
6	101	100	96	95	3.5	1.5	2.6	.6	.45	.42	.38	.21								
7	100	100	93	97	2.1	1.5	1.4	.9	.30	.16	.27	.14	.2	.5	.5					
8	100	94	91	92	2.4	.8	.8	.5	.27	.16	.19	.23	.1							
9	97	97	90	96	3.7	.9	.6	1.3	-	.31	.18	.16	.2					600		
10	94	98	96	93	3.9	1.1	2.3	2.7	.44	-	.23	.19		1.3						300
11	92	96	93	-	4.4	1.2	.6	-	-	.36	.18	-								
12	92	101	98	-	4.9	3.2	2.5	-	.20	.40	.16	-	.1		.1					
13	91	97	86	-	2.3	1.7	2.0	-	.27	.41	.20	-		.2						
14	90	86	82	-	1.5	1.5	.3	-	.32	.04	.19	-	.8						450	
15	85	85	80	-	1.6	1.5	.9	-	.20	.20	.21	-	.1							
16	96	92	80	-	2.6	1.5	1.0	-	.28	.36	.12	-			1.3			450		
17	101	96	82	-	2.9	1.0	1.3	-	.45	.11	.08	-								
18	96	94	87	-	5.4	1.2	1.2	-	-	.57	.18	-		.1						
19	98	79	88	-	2.8	.5	2.0	-	-	.15	.25	-					300			
20	100	88	93	-	1.7	.9	1.0	-	.13	.17	.14	-								
21	103	92	89	-	1.0	.5	.5	-	.28	.15	.20	-								
22	104	95	88	-	1.4	1.1	1.8	-	.37	.30	.27	-								
23	103	101	85	-	2.9	2.7	3.6	-	.44	.36	.26	-								
24	102	100	86	-	1.5	1.7	1.9	-	.43	.33	.20	-								
25	100	97	84	-	2.5	1.1	1.9	-	.40	.20	.20	-			.1					
26	95	97	81	-	5.1	1.8	.9	-	.43	.14	.18	-								
27	85	103	82	-	4.1	1.3	1.9	-	.29	.53	.16	-					200			
28	87	105	87	-	2.4	.5	2.9	-	.05	.39	.08	-								
29	91	94	86	-	.5	.8	2.6	-	.20	.28	.32	-	.4	.6						
30	88	87	79	-	3.3	5.2	2.1	-	.28	.21	.21	-	.9							
31	97	86		-	1.6	2.0		-	.28	.21		-	.1							

[a] T=temperature, W=wind in mph, E=evaporation in in., P=precipitation in in., HFC=Avg. horn flies/head

Table 12.--The effects of weather on horn fly populations at Lake Carl Blackwell 1964 for the months of July, August, September, and October.

Date	T[a] Jul	T Aug	T Sep	T Oct	W Jul	W Aug	W Sep	W Oct	E Jul	E Aug	E Sep	E Oct	P Jul	P Aug	P Sep	P Oct	HFC Jul	HFC Aug	HFC Sep	HFC Oct
1	91	99	94	78	4.6	1.8	3.8	3.7	.61	-	.44	.10	.1							
2	98	102	93	77	1.9	3.9	5.5	5.5	.51	-	.38	.28								
3	100	105	98	83	2.8	4.1	4.9	1.7	.53	.64	.37	.27							800	450
4	99	107	94	74	2.8	3.8	3.7	7.4	-	.51	-	.48								
5	103	109	92	69	2.5	1.8	4.5	2.3	-	.48	.28	.24								
6	103	107	92	71	4.6	1.7	5.3	1.8	.82	.40	.27	.03						150		
7	107	105	90	79	5.5	2.7	3.8	7.0	.63	.46	.46	.32		.3						
8	103	98	90	75	3.8	1.6	6.3	5.9	.38	.43	.34	-								
9	107	99	93	65	4.8	2.2	4.1	1.8	.67	.46	.30	.19					25			
10	91	108	96	69	3.4	2.4	4.8	3.3	.27	.58	.31	.16	.1	.1					650	250
11	96	105	93	69	4.5	3.7	7.3	2.8	.32	-	-	.21			1.7					
12	90	88	94	70	6.1	3.4	4.9	2.9	.48	.39	-	.04								
13	88	85	78	72	6.1	2.3	3.6	1.0	-	.16	.29	.13				.1				120
14	98	85	85	71	2.2	3.4	5.6	.6	.77	.30	.45	.09								
15	98	78	75	76	5.8	3.8	1.3	1.3	.75	.47	.02	.21		2.3						
16	97	81	73	82	8.3	2.3	1.3	3.3	.50	.17	.08	.19			.1		75			
17	97	82	76	89	6.1	1.1	4.1	2.4	.80	.99	.08	.21			.2				500	250
18	96	89	86	78	5.5	2.1	2.1	7.7	.49	.99	.24	.22		.9						
19	98	89	86	65	3.8	.8	1.7	3.7	.78	.25	.20	.30								
20	99	95	88	77	5.3	3.0	5.2	2.0	.46	.53	.25	.10			.1			150		
21	103	92	77	87	3.0	4.6	1.0	.7	-	.29	.05	-		.2	.1					
22	103	85	78	82	3.1	1.8	1.9	3.1	.74	.50	.05	.18			.3					
23	106	90	78	79	3.9	2.2	3.9	2.2	.76	.27	.33	.14					110			
24	106	91	78	75	3.3	1.6	1.5	2.6	.44	.28	.18	.36								200
25	103	84	80	74	2.8	3.8	4.3	6.7	.56	.48	.29	-		.6		.4				
26	103	88	83	72	4.8	2.5	9.3	1.3	-	.86	.30	-		2.0		.1				
27	99	87	80	70	2.3	3.9	3.6	2.9	-	.13	.35	.05								
28	100	91	71	77	6.3	5.4	7.1	.6	.31	.41	.18	.07		.8						
29	95	99	69	77	5.2	2.7	1.8	.8	.36	.25	.08	.15								
30	99	93	72	82	2.8	3.7	1.4	-	.35	.42	.15	.17		.2						
31	97	93		82	4.6	2.3		2.1	.56	.39		-								

[a] T=temperature, W=wind in mph, E=evaporation in in., P=precipitation in in., HFC=Avg. horn flies/head

Table 13.--The effects of weather on horn fly populations at Fort Supply 1964 for the months of August and September.

Date	T[a] Aug	T Sep	W Aug	W Sep	E Aug	E Sep	P Aug	P Sep	HFC Aug	HFC Sep
1	98	97	5.2	3.3	.52	.53				
2	102	97	9.7	2.5	.77	.51				
3	106	100	7.7	1.8	.76	.62			65	
4	107	100	4.9	.8	.65	.49				
5	104	94	.2	1.0	.40	.35				
6	109	95	.5	1.5	.48	.52				
7	107	95	2.3	1.8	.46	.51				350
8	93	97	1.8	3.9	.45	.47				
9	108	97	2.1	1.6	.48	.47				
10	106	101	6.1	.5	.61	.55			112	
11	88	86	1.3	4.7	.54	.48				
12	92	74	2.3	2.6	.50	.01		.2		
13	92	82	1.1	2.9	.24	.25	.9			
14	90	89	3.4	8.4	.44	.37				
15	76	88	3.4	4.2	.14	.36	1.0			275
16	85	62	.4	5.0	.14	.01		.6		
17	88	74	1.1	1.2	.22	.01			58	
18	85	85	1.0	1.0	.30	.13	.1	.1		
19	90	90	.7	2.8	.12	.29				
20	90	70	3.4	4.8	.43	.27		.5		
21	88	76	1.3	2.4	.36	.10				
22	85	88	.3	2.0	.29	.16				125
23	92	85	.1	1.7	.33	.26				
24	95	77	1.1	2.0	.42	.30			135	
25	95	81	4.3	4.5	.52	.25				
26	94	80	.7	7.2	.24	.33				
27	97	75	3.6	5.6	.41	.39				
28	95	72	2.9	2.4	.46	.21				
29	102	82	.5	2.5	.30	.24				52
30	97	80	3.4	2.8	.50	.23				
31	97		1.1		.31				350	

[a] T=temperature, W=wind in mph, E=evaporation in in., P=precipitation in in., HFC=Avg. horn flies/head

When air movement exceeded a velocity of 15 to 20 mph the adult horn flies were observed to burrow between the hair and to remain close to the skin of the host animal. In light breezes the flies were found on the sheltered side of the animal, remaining there with very little flight activity for extended periods or until the animal changed directions.

Increased numbers of horn flies were observed during the summer months when temperatures of less than 37.7 C were combined with precipitation. This is exemplified by the data for July and August 1963, the last of August and first of September 1964 at Lake Carl Blackwell and August 1964 at Fort Supply, Oklahoma.

The results obtained in July 1963, July 1964, and August 1964 at Lake Carl Blackwell indicate that after a moderate rain even when temperatures reach 37.7 C the horn fly population continues to rise for a short period of time. However, if the temperatures remain extremely high for an extended period of time the populations will decrease as shown in Table 11 for July 1963 at Lake Carl Blackwell. This type of situation caused a similar fluctuation in the horn fly populations in August 1964 at Lake Carl Blackwell and August 1964 at Fort Supply, Oklahoma (Tables 12 and 13).

In the early fall when temperatures start to decrease, regardless of rainfall, there is a decline in population numbers. These results are shown in September 1963, September and October 1964, at Lake Carl Blackwell, and September 1964 at Fort Supply, Oklahoma.

The results of the August 1964 study, conducted to determine the time of day that adult horn flies seek a host, are shown in Table 14.

Table 14.--Mean numbers of horn flies counted during two time periods during the day in August 1964 at Lake Carl Blackwell.

Time of Day	Mean	
9:00 - 11:00 am	1.940	
		**
3:00 - 5:00 pm	4.900	

** Mean horn fly numbers are significantly different from each other at the .01 level of probability.

The flies were observed to move quite rapidly to the test animal during the 3:00 to 5:00 pm tests. More accurate data and easier handling of the test animal could be obtained by the use of two experimenters, one leading the animal and the other making the observations.

To obtain more information the tests could start earlier in the morning and be continued at hourly intervals throughout the day. These tests would serve to determine the time of emergence and host seeking as well as the effects of different barrier situations on the distribution of the adult horn flies.

Larval Metabolism Studies

Metabolism Measurements. The mean temperature X days numbers of the horn fly larvae in μl O_2/mg dry wt/hour are shown in Table 15.

The results of the Analysis of Variance for the 4 X 3 factorial design utilized to compare the effects of four constant temperatures on three time periods are shown in Table 16.

This study indicates that the oxygen consumption of larvae held at constant temperatures of 4.5 and 10 C were significantly different at the .005 level of probability from those held at 16 and 21 C over the entire time period of 120 hours. The analysis of variance indicates that this was the only combination of temperature means shown to be significantly different at the .05 level of probability or higher. This was thought to be due to the increase and decrease of the larval metabolism during the changes from one instar to another, since these larvae were observed in the late third instar by the end of the 120 hours.

Table 15.--Temperatures X hours means of larval oxygen consumption for the 4 X 3 factorial, in µl O_2/mg dry wt/hour.

	Hours				
Temperature C	24	72	120	Mean	
4.5	5.57	7.55	7.23	6.78	**
10.0	4.50	5.50	6.75	5.58	
16.0	4.91	3.83	2.95	3.89	
21.0	4.23	3.04	1.73	3.00	
Mean	4.80	4.98	4.66	4.81	

** Those mean numbers not connected by a line are significantly different at the .01 level of probability.

The lower oxygen consumption obtained from the larvae held at the higher temperatures could possible be attributed to a period in the later instars in which the larvae receive their oxygen from anaerobic metabolism.

No significant differences were found between the three different time periods utilized during this study. The oxygen consumption rate of larvae held at the two lower temperatures essentially increased over the 120 hour period, while the larvae held at the two higher temperatures decreased considerably over the same time period.

It is conceivable that these results were due to the chance of measuring the oxygen consumption rates during the time when the larvae were in a state of low oxygen requirement as discussed above.

Table 16.--Analysis of variance for metabolism measurements on horn fly larvae held at constant temperatures.

Source		df	SS	MS	F
Total		60	1916.187		
Mean		1	1393.296		
Main plots		19	401.329	21.122	1.720
Replication		4	125.164	31.291	2.548
Temperature		3	128.827	42.942	3.497*
Temperature Linear	1		127.257	127.257	10.364**
Temperature Quadratic	1		.345	.345	.028
Temperature Cubic	1		1.225	1.225	.099
Error (a)		12	147.338	12.278	
Sub plots		40	121.589	3.039	1.783
Days		2	.989	.494	.289
Days Linear	1		.191	.191	.112
Days Quadratic	1		.798	.798	.468
Days X Temperature		6	66.050	11.008	6.460***
Days L X Temp L	1		34.752	34.752	20.394***
Days L X Temp Q	1		.809	.809	.474
Days L X Temp C	1		8.908	8.908	5.227*
Days Q X Temp L	1		2.035	2.035	1.194
Days Q X Temp Q	1		1.744	1.744	1.023
Days Q X Temp C	1		17.802	17.802	10.447***
Error (b)		32	54.550	1.704	

* Significant at the .05 level of probability.
** Significant at the .01 level of probability.
*** Significant at the .005 level of probability.

The effect of shipping these larvae through the mail and any differences due to handling did not show a significance (replication) at the .05 level of probability, although some differences were observed.

Control

<u>Lake Carl Blackwell 1963</u>. The effects of the five treatments

utilized for horn fly control at Lake Carl Blackwell in 1963 are shown in Table 17.

Table 17.--Horn fly counts on cattle at Lake Carl Blackwell in 1963.

	Treatments				
Date	Block	Granules	Block	Granules	Non-Med.
7/5/63	250	600	300	300	300
7/20/63	300	350	300	400	300
7/27/63	75	50	40	85	200
8/2/63	10	10	35	40	200
8/9/63	180	70	250	600	600
9/16/63	140	85	200	250	450
9/4/63	125	150	250	250	400
9/14/63	100	125	250	200	450
9/19/63	150	150	250	150	400
10/10/63	100	----	50	150	300
Average Count	131	124	181	236	367
Percent [a] Control	65	66	51	36	0.0

[a] The average horn fly control in the four treated pastures was 55%.

The mineral and ronnel consumption at Lake Carl Blackwell in 1963 are shown in Table 18 for each consumption period.

The medicated mineral formulations used on these tests held the horn fly populations considerably below those on cattle consuming a non-medicated formulation. The groups receiving the granulated formulation had a higher average percentage of horn fly control

Table 18.--Total mineral and ronnel consumption during the Lake Carl Blackwell Trial in 1963

Treatments	Consumption Periods						
	21 days	15 days	7 days	6 days	14 days [a]	19 days	15 days
Block							
gm/hd/day, min. mix.	31.98	21.33	11.43	94.62	21.03	44.70	0.0
mg/kg/day, ronnel	4.30	2.86	1.54	12.72	2.83	6.01	0.0
Granules							
gm/hd/day, min. mix.	44.73	18.27 [b]	58.77	77.82	28.41	41.13	28.80
mg/kg/day, ronnel	6.00	2.45	7.90	9.12	3.85	5.53	3.87
Block							
gm/hd/day, min. mix.	36.24	45.72	39.18	43.86	26.43	34.65	22.38
mg/kg/day, ronnel	4.95	6.15	5.27	5.89	3.54	4.65	3.00
Granules							
gm/hd/day, min. mix	47.37	9.39 [b]	20.16	36.45	14.61	37.14	65.40
mg/kg/day, ronnel	6.37	1.26	2.75	4.90	1.96	4.99	8.80
Non-medicated							
gm/hd/day, min. mix.	27.24	37.65	10.08	47.04	54.24	25.98	57.39

[a] All cattle groups were rotated 10 days prior to this consumption measurement.

[b] The cattle groups receiving this treatment were moved 7 days prior to the date that this consumption measurement was made.

than those receiving the block form, but two groups receiving the same formulation were inconsistant in control as well as consumption.

The horn fly control obtained by the utilization of free-choice consumption of medicated minerals depends upon the daily intake of approximately 4.5 mg/kg/day of the active systemic chemical, ronnel.

Table 19 shows the average consumption of ronnel for the entire treatment period of 75 days at Lake Carl Blackwell 1963.

Table 19.--Average consumption of ronnel during Lake Carl Blackwell trial conducted in 1963.

	Treatments			
	Block	Granules	Block	Granules
ronnel mg/kg/day	4.30 [a]	5.53	4.77	4.43[a]

[a] The recommended consumption of ronnel for the 75 day treatment period was 4.5 mg/kg/day.

In situations where large pastures and small numbers of cattle per pasture are utilized it is extremely difficult to obtain the required consumption on a per day basis. The consumption data from these tests indicate that the recommended dosage was almost obtained, but a comparison with the horn fly control data shows that the mineral was consumed inconsistantly.

Some of the cattle groups were rotated twice during this trial to better utilize the pasture vegetation and this factor seemingly added to the inconsistant mineral consumption. The cattle groups were observed to settle down and resume a normal foraging pattern after approximately five days from the time they were rotated. When such a rotation and period of re-adjustment occurred it required approximately another five days to re-locate the mineral boxes in areas offering maximum access to the minerals.

The cattle in these groups obtained their water source from Lake Carl Blackwell, each pasture utilizing thousands of feet of lake frontage. The change in the drinking site and corresponding changes in the loafing areas necessitated the numerous movements of the mineral boxes. These factors must be considered when evaluating the free-choice feeding of medicated mineral mixtures to rangeland cattle in Oklahoma.

The block formulations were observed to breakdown very rapidly when exposed to rainfall, while little if any of the granular material was lost. These results indicate the necessity of using covered mineral feeders which would protect the mineral blocks from rainfall.

Lake Carl Blackwell 1964. The advantage of pre-treatment spraying, which reduces the horn fly populations until a sufficient amount of ronnel has been consumed to sterilize the manure, can be observed by comparing the results contained in Tables 20 and 21 of the Lake Carl Blackwell 1964 trials. The horn fly populations on the non-sprayed groups almost consistently doubled the counts on the groups which received the pre-treatment spraying.

The larval counts give an indication of the degree to which the manure was sterilized. These data when compared to the adult counts indicate that there were some individual cows within the groups which were consuming very little if any medicated minerals. However, there was only one observation made where a medicated treatment showed higher larval counts than the non-medicated check group.

Table 20.--Adult and larval horn fly counts and percent control on cattle groups receiving pre-treatment spraying at Lake Carl Blackwell in 1964.

	Treatments							
	1 [a]		2 [b]		3 [c]		4 [d]	
Date	A	L	A	L	A	L	A	L
7/9/64	15	.6	15	.1	5	.2	15	5.6
7/16/64	15	1.7	15	.3	5	.4	30	3.4
7/23/64	15	4.5	20	5.7	10	.1	35	5.1
8/6/64	25	1.0	20	6.4	10	.3	75	5.2
8/13/64	30	2.3	20	.9	15	.1	115	2.6
8/20/64	55	.4	55	2.4	30	1.2	135	11.9
9/3/64	125	19.5	150	21.2	175	17.4	450	29.3
Average Count	40	4.0	42	5.0	36	3.0	122	9.0
Percent [e] Control	67	56	66	44	70	67	0	0

[a] Contained 6% ronnel base material.
[b] Contained 4% ronnel - 2 parts base material + 1 part bone meal.
[c] Contained 4% ronnel - 2 parts base material + 1 part dicalcium phosphate.
[d] Non-medicated base material.
[e] The average horn fly control in the three treated groups was Adult 68% and the Larvae 56%.

The mineral and ronnel consumption at Lake Carl Blackwell in 1964 is shown in Tables 22 and 23 for the consumption periods. The consumption of medicated minerals was shown to be highly variable over this trial. The cattle on two similar trials receiving the same treatments varied to a great extent in their consumption levels. Four groups of cattle receiving medicated minerals failed to consume the recommended levels of ronnel as indicated in Table 24.

Table 21.--Adult and larval horn fly counts and percent control on cattle groups receiving no pre-treatment spraying at Lake Carl Blackwell in 1964.

	Treatments [a]							
	1		2		3		4	
Date	A	L	A	L	A	L	A	L
7/9/64	45	.1	50	.3	25	.6	25	2.2
7/16/64	50	2.1	55	.5	30	1.7	75	3.3
7/23/64	75	3.3	35	.7	35	9.7	110	6.2
8/6/64	75	10.8	55	6.7	60	1.0	150	15.6
8/13/64	75	.3	50	2.4	65	2.8	120	10.6
8/20/64	100	.3	125	.3	100	11.2	150	13.1
9/3/64	400	12.8	450	15.4	250	19.3	800	26.1
Average Count	117	4.0	117	4.0	81	7.0	204	11.0
Percent [b] Control	43	64	43	64	60	36	0	0

[a] The oral treatments in this test were as given in Table 20.
[b] The average horn fly control in the three treated groups was Adult 49% and the Larvae 55%.

The effects of cattle rotation can be observed in the consumption data of Tables 22 and 23 which are similar to those results observed in the 1963 Lake Carl Blackwell trial.

Attempts were made throughout this trial to find solutions to the consumption rate problems encountered in the 1963 trial at Lake Carl Blackwell. The cattle groups were closely observed and mineral boxes were moved according to the changing habits of the cattle. The large water source and continuously changing loafing areas rendered permanent placing of the mineral boxes impracticable.

Table 25 shows the amount of mineral mixture lost due to

Table 22.--Mineral and ronnel consumption of the cattle groups receiving pre-treatment spraying at Lake Carl Blackwell in 1964.

Treatments[a]	Consumption Periods						
	18 days	7 days	7 days	14 days	7 days	7 days	14 days
1							
gm/hd/day min. mix.	7.80	37.97	8.93[b]	30.15	35.74	67.01	35.84
mg/kg/day ronnel	1.15	5.58	1.31	4.43	5.25	9.85	8.21
2							
gm/hd/day min. mix.	28.66	49.14	44.67	27.92[c]	51.38	62.55	24.57
mg/kg/day ronnel	2.81	4.81	4.37	2.73	5.03	6.12	2.40
3							
gm/hd/day min. mix.	27.80	44.67	33.50	18.98[c]	24.57	87.12	25.19
mg/kg/day ronnel	2.72	4.37	3.28	1.86	2.40	8.53	2.51
4							
gm/hd/day min. mix.	25.19	33.37	11.77[b]	7.85	41.22	35.33	39.26
mg/kg/day ronnel	——	——	——	——	——	——	——

[a] The oral treatments used in this test were as indicated in Table 20.
[b] Cattle groups receiving this treatment were rotated 4 days prior to this consumption measurement.
[c] Cattle groups receiving this treatment were rotated 8 days prior to this consumption measurement.

Table 23.--Mineral and ronnel consumption of the cattle groups receiving no pre-treatment spraying at Lake Carl Blackwell in 1964.

Treatments[a]	Consumption Periods 18 days	7 days	7 days	14 days	7 days	7 days	14 days
1							
gm/hd/day min. mix.	21.71	40.21	6.70[b]	12.28	17.87	75.95	33.50
mg/kg/day ronnel	3.19	5.90	.98	1.80	2.63	11.16	4.92
2							
gm/hd/day min. mix.	43.43	91.59	73.72	35.74	55.84	69.25	35.74
mg/kg/day ronnel	4.25	8.97	7.22	3.50	5.46	6.78	3.50
3							
gm/hd/day min. mix.	36.27	62.55	24.57[b]	31.27	44.67	71.48	33.50
mg/kg/day ronnel	3.55	6.13	2.41	3.15	4.45	7.00	3.15
4							
gm/hd/day min. mix.	20.85	22.33	8.93[b]	10.05	22.33	87.12	50.26
mg/kg/day ronnel	----	----	----	----	----	----	----

[a] The oral treatments used in this test were as indicated in Table 20.

[b] Cattle groups receiving this treatment were rotated 5 days prior to this consumption measurement.

weather conditions during the 1964 trial conducted at Lake Carl Blackwell.

Table 24.--Average consumption of ronnel in mg/kg/day in the Lake Carl Blackwell trial in 1964, for the entire treatment period of 97 days.

	Treatments		
	1	2	3
Sprayed	5.11	4.04	3.67
Not Sprayed	4.37	5.67	4.26

The oral treatments in this test were as given in Table 20.
The recommended consumption of ronnel for the 97 day treatment period was 4.5 mg/kg/day.

Table 25.--The amount of mineral material lost due to weather conditions at Lake Carl Blackwell in 1964.

Date	Number of Pounds Lost
7/9/64	.50
7/16/64	.25
7/23/64	.25
8/6/64	.50
8/13/64	.75
8/20/64	5.00
9/3/64	6.00
Total Lost	13.25

The use of the weather standard mineral box utilized on this trial showed evidence that rainfall washed away a considerable amount of the material from the rangeland mineral boxes which were open to the effects of weather. The data recorded for August 20 and September 3, 1964 in Table 25 when compared with the rainfall data of Table 12 show the effects of hard driving rainfall noted by the author previous to these measurements. Slow, easy rainfall encountered on previous days did not show too great a loss of the minerals. Wind was observed to cause very little if any loss from the mineral boxes.

Fort Supply 1964. The data contained in Table 26 show the average mineral consumption in gm/hd/day for the entire treatment period of 80 days at Fort Supply, Oklahoma in 1964.

Table 26.--Average mineral consumption in gm/hd/day at Fort Supply, Oklahoma 1964.

Treatments				
1[a]	2[b]	3[c]	4[d]	5[e]
63.46	40.77	32.40	26.03	34.69

[a] Non-medicated base mineral mixture.
[b] Non-trace mineralized base mixture - 5.5% ronnel.
[c] Base mineral mixture + 2:1 Ca to P - 6.0% ronnel.
[d] Base mineral mixture + 3:1 Ca to P - 6.0% ronnel.
[e] Complete trace mineralized base mixture - 6.0% ronnel.

The mineral and ronnel consumption at Fort Supply, Oklahoma in 1964 is shown in Table 27.

The addition of calcium and phosphorus to the base mineral mixtures successfully regulated the consumption of ronnel very close to the recommended dosage of 4.5 mg/kg/day. The 2:1 ratio was found to be the best ratio since three treatment groups receiving the 3:1 ratio did not consume the recommended amount.

The results of the pasture means comparisons at Fort Supply, Oklahoma in 1964 are shown in Table 28. These data indicate that steers on continuous yearlong grazing pasture situations consumed more mineral than those utilized on pasture types in their respective comparisons. The heavy stocking rate pastures were the only groups which seemed to have low consumption problems.

Table 27.--Mineral and ronnel consumption at Fort Supply, Oklahoma in 1964.

Treatment - [a] Pasture Number[b]	Consumption Periods 20 days	15 days	15 days	15 days	15 days	Pasture Average
1-17						
gm/hd/day min. mix.	68.02	115.89	41.06	23.17	45.35	59.28
mg/kg/day ronnel	---	---	---	---	---	---
1-27cd						
gm/hd/day min. mix.	77.74	103.65	77.74	25.91	49.66	67.62
mg/kg/day ronnel	---	---	---	---	---	---
2-19						
gm/hd/day min. mix.	54.98	32.50	30.23	30.23	45.35	39.68
mg/kg/day ronnel	8.33	4.92	4.58	4.58	6.84	6.01
2-27ab						
gm/hd/day min. mix.	16.19	35.41	30.23	41.03	53.12	34.01
mg/kg/day ronnel	2.45	5.36	4.58	6.21	8.05	5.15
2-32a						
gm/hd/day min. mix.	55.93	48.37	34.26	56.43	34.26	46.48
mg/kg/day ronnel	8.41	7.33	5.19	8.55	5.19	7.04
2-23c						
gm/hd/day min. mix.	9.07	40.31	68.52	60.46	47.36	42.89
mg/kg/day ronnel	1.37	6.11	10.38	9.16	7.18	6.50
3-32c						
gm/hd/day min. mix.	2.26	10.58	77.09	33.25	18.14	26.64
mg/kg/day ronnel	.37	1.74	12.74	5.49	2.19	4.40
3-18						
gm/hd/day min. mix.	32.87	28.34	23.61	36.46	28.34	30.11
mg/kg/day ronnel	5.43	4.68	3.90	6.03	4.68	4.97
3-26b						
gm/hd/day min. mix.	36.84	42.32	44.59	45.35	20.40	37.83
mg/kg/day ronnel	6.09	6.99	7.37	7.50	3.37	6.25
3-21						
gm/hd/day min. mix.	32.02	31.74	19.73	43.83	49.12	35.00
mg/kg/day ronnel	5.29	5.24	3.18	7.24	8.12	5.78

Table. 27.--(Continued).

Treatment - [a] Pasture Number [b]	Consumption Periods 20 days	15 days	15 days	15 days	15 days	Pasture Average
4-24						
gm/hd/day min. mix.	17.85	22.29	38.54	40.81	51.39	33.16
mg/kg/day ronnel	2.95	3.68	6.37	6.74	8.49	5.48
4-37ab						
gm/hd/day min. mix.	30.61	32.12	17.76	48.37	29.85	31.67
mg/kg/day ronnel	5.06	5.31	2.93	7.99	4.93	5.23
4-39e						
gm/hd/day min. mix.	59.71	24.85	12.76	10.07	16.12	24.43
mg/kg/day ronnel	9.87	4.10	2.10	1.66	2.66	4.04
4-39w						
gm/hd/day min. mix.	42.32	30.73	19.14	35.27	28.21	31.83
mg/kg/day ronnel	6.99	5.08	3.16	5.96	4.66	5.26
4-38a						
gm/hd/day min. mix.	14.36	21.83	14.78	20.49	15.11	14.61
mg/kg/day ronnel	2.37	3.61	2.44	3.38	2.49	2.41
4-38c						
gm/hd/day min. mix.	23.80	24.69	4.53	19.65	28.72	20.50
mg/kg/day ronnel	3.93	4.08	.74	3.24	4.74	3.39
5-33ab						
gm/hd/day min. mix.	50.26	44.84	37.28	28.21	34.26	39.68
mg/kg/day ronnel	8.31	7.41	6.16	4.66	5.66	6.56
5-41s						
gm/hd/day min. mix.	37.79	47.36	20.15	32.58	30.23	29.22
mg/kg/day ronnel	6.24	7.83	3.33	5.38	4.99	4.83
5-40e						
gm/hd/day min. mix.	59.96	53.41	37.95	20.82	41.31	38.23
mg/kg/day ronnel	9.91	8.83	6.27	3.44	6.83	6.32
5-42n						
gm/hd/day min. mix.	49.88	32.24	15.62	29.72	24.69	31.65
mg/kg/day ronnel	8.24	5.33	2.58	4.91	4.08	5.23

a Treatment numbers defined in Table 26.

b Pasture numbers defined in Table 5.

The results of the pasture means comparisons at Fort Supply, Oklahoma in 1964 are shown in Table 28.

Table 28.--Comparisons of the effects of pastures and treatments on mineral consumption at Fort Supply, Oklahoma in 1964.

Pasture [a] Numbers	Treatment [b] Numbers	Average Consumption gm/hd/day
17 - 19	1 vs 2	59.28 - 39.68
27ab - 27cd	1 vs 2	34.01 - 67.62
19 - 18	2 vs 3	39.68 - 30.11
32a - 32c	2 vs 3	46.48 - 26.64
23c - 26b	2 vs 3	42.89 - 37.83
27ab vs 32a	2	34.01 - 46.48
18 - 37ab	3 vs 4	30.11 - 31.67
21 - 24	3 vs 4	35.00 - 33.16
32c vs 21	3	26.64 - 35.00
38a - 40e	4 vs 5	14.61 - 38.23
39e - 41s	4 vs 5	24.43 - 29.22
38c - 42n	4 vs 5	20.50 - 31.65
39w - 33ab	4 vs 5	31.83 - 39.18
37ab vs 38a	4	31.67 - 14.61
24 vs 39e	4	33.16 - 24.43

[a] Pasture type identification as shown in Table 5.
[b] Treatment identification as shown in Table 26.

The smaller pastures containing a single water source utilized in this trial provided excellent conditions for using free-choice minerals. The loafing areas for these steers were observed to be in the windmill and mineral feeder area which is ideal for this method of horn fly control.

The steers used in treatments 4 and 5 were rotated every 15 days throughout the trial. The data shown in Table 27 indicate some variations in consumption over the five measurement periods. However, most of the groups averaged close to or over the recommended dosage intake. This was believed to be due to the single location of the water source combined with the smaller pasture sizes, since only one pasture contained over 50 acres.

The results of the pasture and treatment comparisons show that consumption varied among treatment formulations and among pasture types on the same formulation. The results shown in Tables 26 and 27 indicate that the consumption rates of the non-medicated formulations was considerable higher than the medicated formulations.

The horn fly control shown in Tables 29 and 30 indicate that the daily consumption of ronnel approached the recommended 4.5 mg/kg/day over the entire test period. The mean numbers of horn flies per day cbserved show that the populations were held at less than 55 adult flies per head and the larvae to less than 13 per sample over the entire test period. The average counts from the four medicated treatments show horn fly numbers of less than 16 adult flies per head and less than 4.3 larvae per sample.

The results of the assay conducted by the Dow Chemical Company shown in Table 31 indicate the value of whirlwind mineral feeders under range conditions. These analyses show a loss of 2.5 to 6% ronnel in the initial formulations due to exposure. Some of this loss is probably due to exposure in the containers which occurred after they were opened and prior to their utilization on the trial.

Table 29.--Adult and larval horn fly counts at Fort Supply, Oklahoma in 1964 by pasture and treatment.

Treatment,[a] Pasture[b]	Dates Counted 7/27/64 A	L	8/3/64 A	L	8/10/64 A	L	8/17/64 A	L	8/24/64 A	L
1, 17	45	75	75	280	135	110	55	55	130	198
1, 27cd	25	45	55	210	90	56	60	32	140	275
2, 19	4	3	5	6	2	0	0	0	5	7
2, 23c	10	5	10	17	3	1	0	1	0	10
2, 27ab	5	4	15	2	3	1	0	1	15	5
2, 32a	5	5	10	24	0	2	0	0	0	4
3, 18	0	0	0	0	0	0	0	3	2	14
3, 21	0	0	5	1	5	0	0	0	0	5
3, 26b	4	2	10	3	5	0	0	0	2	28
3, 32c	0	3	1	0	2	0	0	0	0	45
4, 24	0	0	0	0	0	22	1	5	2	19
4, 37ab	5	0	5	0	10	13	5	6	3	9
4, 39e	0	0	4	0	5	9	0	10	1	22
4, 38a	5	0	4	0	0	37	0	0	0	5
4, 38c	0	0	5	0	1	33	0	0	0	13
4, 39w	0	0	0	0	2	10	0	2	0	4
5, 40e	10	10	2	5	10	0	0	0	5	0
5, 41s	0	5	0	0	5	2	0	1	10	3
5, 33ab	15	2	5	10	0	0	0	2	3	21
5, 42n	15	3	1	8	5	0	0	1	2	22

Table 29.--(Continued).

Treatment,[a] Pasture [b]	Dates Counted 8/31/64 A	L	9/7/64 A	L	9/15/64 A	L	9/22/64 A	L	9/29/64 A	L
1, 17	400	500	450	450	300	150	150	85	50	75
1, 27cd	300	275	250	400	250	85	100	65	55	53
2, 19	50	0	20	60	30	0	15	0	15	4
2, 23c	25	0	60	10	25	0	5	0	10	60
2, 27ab	75	0	40	25	0	0	10	0	15	10
2, 32a	10	55	25	10	5	1	0	0	10	15
3, 18	100	65	5	0	0	0	10	10	13	10
3, 21	5	10	60	15	10	2	15	1	10	10
3, 26b	50	50	30	60	30	2	15	0	10	26
3, 32c	25	25	7	10	5	1	0	11	10	20
4, 24	15	35	25	0	0	14	0	5	10	0
4, 37ab	75	15	15	0	0	15	5	15	13	1
4, 39e	25	45	40	60	45	0	5	10	40	10
4, 38a	10	50	40	40	25	1	5	4	10	0
4, 38c	25	5	25	20	10	0	5	7	15	4
4, 39w	15	25	25	33	15	0	5	0	15	0
5, 40e	100	54	50	0	0	0	10	60	15	10
5, 41s	10	10	40	0	0	0	0	11	10	6
5, 33ab	50	0	25	10	5	1	0	20	10	8
5, 42n	15	25	30	30	15	2	10	9	15	20

[a] Treatment identification as shown in Table 26.
[b] Pasture-type identification as shown in Table 5.

Table 30.--The effects of five treatments on adult and larval horn fly populations at Fort Supply, Oklahoma in 1964.

	Treatment Numbers [a]									
	1		2		3		4		5	
Date	A [b]	L [c]	A	L	A	L	A	L	A	L
7/27/64	35	15	6	2.0	1	0.5	3	0.0	10	2.2
8/3/64	65	61	10	6.0	4	0.4	3	0.0	2	2.3
8/10/64	112	21	2	0.5	3	0	1	8.0	5	0.2
8/17/64	58	11	0	0.2	0	0.3	1	1.5	0	0.3
8/24/64	135	59	5	3.0	1	9.2	1	4.8	5	4.6
8/31/64	350	97	52	7.0	32	8.9	27	12.0	43	15.0
9/7/64	350	106	41	13.0	28	8.5	28	10.0	36	4.0
9/15/64	275	29	15	0.1	11	0.5	15	2.0	5	0.3
9/22/64	125	19	8	0.0	10	2.2	4	2.7	5	10.0
9/29/64	52	16	12	11.0	12	6.6	17	1.0	10	4.4
Average Count	155	43.4	15	4.3	10	3.7	10	4.2	12	4.3
Percent [d] Control	0	0	90	90	93	91	93	90	92	90

[a] Treatment numbers defined in Table 26.
[b] Average flies per head.
[c] Average larvae per fecal sample
[d] The average horn fly control in the four medicated treatments was Adult 92% and the Larvae 90%.

Table 31.--Amount of ronnel lost as a result of weather exposure for 15 days in whirlwind feeders at Fort Supply, Oklahoma in 1964.

Treatment [a]	Percent ronnel used in Feed	ronnel Recovered
2	5.5	5.23
3	6.0	5.85
5	6.0	5.62

[a] Treatment identification shown in Table 26.

SUMMARY AND CONCLUSIONS

Laboratory and field experiments were conducted to determine the relation of ecological factors to the distribution and control of the horn fly under range conditions.

The pupal stage of horn fly development was the only stage observed to survive the winter in Oklahoma. The open grassland pastures provided the best conditions for horn fly winter survival. All pupae were found beneath fecal deposits, either on the soil surface or in the soil to a depth of $1\frac{1}{2}$ inches. The soil surface was the most common site. In the heavily timbered pasture the only pupae observed to survive the winter were found during the month of September and were more frequently found beneath the surface of the soil.

The interpretation of data collected from both pasture types indicated that the pupae preferred the center area beneath the fecal deposit rather than at the edge of the pad. The center area of the fecal deposits seemed to provide more protection from the climatic conditions.

The largest number of pupae were found associated with fecal deposits having a diameter of 8 to 16 inches and a thickness of 3 to 6 inches. Fecal deposits of this size were observed to provide better protection due to their resistance to dispersion of the component parts by the climatic elements.

The most important weather influences on horn fly populations were temperature and precipitation. Wind and evaporation appeared to have little influence on the population numbers. Mean daily temperatures of less than 37.7 C combined with precipitation during the summer months caused increased numbers of horn flies. After a period of rainfall even though daily mean temperatures were in excess of 37.7 C, the horn fly populations were observed to increase in numbers for a short period of time. In such cases, however, if for a short period of time the temperatures remained extremely high the populations showed a definite decline. Regardless of rainfall, decreasing fall temperatures caused a decline in population numbers.

Larger numbers of emerging horn flies sought their hosts in the afternoon hours of 3:00 to 5:00 than in the morning from 9:00 to 11:00. The testing procedure utilized in this phase of the study was shown to be an effective technique for further investigation.

Constant temperatures of 4.5 and 10 C were observed to increase significantly larval horn fly metabolism more than when compared to 16 or 21 C over a period of 120 hours. This response was thought to be due to the increase or decrease of larval metabolism during the changes from one instar to another, since these larvae were observed to be in the third instar by the end of the 120 hours. The larvae held at 4.5 and 10 C did not change to the second instar during the testing period.

The effects of time during the 24, 72, and 120 hour period was not shown to influence the metabolic rate significantly at the .05 level of probability unless combined with the effects of the constant temperatures.

The control of horn flies using the free-choice medicated mineral mixtures was shown to be effective when the pasture size was small and a single water source per pasture was available.

The consumption rate was observed to be considerably affected by the rotation of the cattle groups. These trials were conducted at Lake Carl Blackwell in 1963 and 1964. The consumption data observed during these tests indicate the intake of ronnel approximated the recommended dosage, but when the data were compared to the horn fly control data it was obvious that the mineral was consumed inconsistantly.

Little difference could be detected between the average consumption rates of the granular and block formulations at Lake Carl Blackwell in 1963. Cattle groups receiving the granulated formulation had an overall higher percentage of horn fly control than those receiving the block form, but the two groups receiving the same formulation had inconsistant control as well as consumption rate. The block formulation appeared to breakdown rapidly when exposed to rainfall.

There was an advantage of pre-treatment spraying to reduce horn fly populations until a sufficant amount of ronnel has been consumed to sterilize the manure. These results were observed in the 1964 Lake Carl Blackwell trial. The average horn fly populations on the non-sprayed groups almost doubled the size of the populations on groups receiving pre-treatment spraying.

Small differences in adult horn fly control were shown between treatments in the 1964 Lake Carl Blackwell trial but the cattle receiving dicalcium phosphate plus the base mineral mixture with 4% ronnel showed considerably higher larval control. These results indicate that most of the cattle on the latter treatment were consuming consistant amounts of the mineral on a daily intake basis.

The data obtained from the weather standard at Lake Carl Blackwell, in 1964, indicated that while hard driving rainfall caused high mineral losses, slow gradual rainfall produced little or no losses. Wind was shown to cause very slight losses from the open mineral boxes.

The addition of calcium and phosphorus to the mix apparently increased the attractiveness of the mixture for the intake of ronnel in this preparation was calculated to be very close to the recommended dosage of 4.5 mg/kg/day. These trials were conducted at Fort Supply in 1964.

Steers on continuous yearlong grazing pasture situations were shown to consume larger amounts of minerals than those of other pasture types in their respective comparisons. These data indicate the importance of the pasture vegetation on the rate of mineral consumption.

There was little difference between the effectiveness of adult and larval horn fly control in the 1964 Fort Supply, Oklahoma trial. The effects of the smaller pasture size and the single water source per pasture increased both the consumption rate and the percent horn fly control.

Chemical assay of mineral samples contained in whirlwind mineral feeders showed little loss of ronnel due to climatic conditions.

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